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PRODUCTIVITY IMPROVEMENTS IN SIMULATION MODELING (PRISM) PROJECT: CONCEPTS AND MOTIVATIONS

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Discrete-event simulation models have been, and continue to be, major decision support aids in logistics capability assessment. Results of a user needs survey conducted by the Air Force Human Resources Laboratory (AFHRL) indicate widespread user dissatisfaction with various aspects of many of these models. The models tend to be difficult to use, insufficiently documented, and difficult to modify, and to require inordinate amounts of data preparation. This paper provides a technical overview of the approach being taken by AFHRL to address these problems under the Productivity Improvements in Simulation Modeling (PRISM) project. The primary objective of this project is to provide a proof of concept for an Integrated Model Development Environment (IMDE). The IMDE is conceived as a software environment, resident upon a computer workstation and designed to use modular, hierarchical, object-oriented software structures. The proposed IMDE would be linked to an intelligent, object-oriented data base that can be accessed by the user to retrieve capability assessment "objects" such as aircraft, aircrews, maintenance equipment, and mission profiles. The development and life-cycle management of object-oriented models would be facilitated by the set of high-level tools provided by the IMDE.

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SUMMARY

Air Force logistics capability assessment is performed by the Air Staff, at the major commands, and at the unit level. This assessment is currently aided by the use of a number of large discrete-event computer simulation models. The results of an Air Force Human Resources Laboratory (AFHRL) user needs survey indicate widespread user dissatisfaction with various aspects of many of these models. The major deficiencies identified include difficulty of use, insufficient documentation, difficulty of modification, and inordinate data preparation requirements. This paper provides a technical overview of the approach being taken by AFHRL to address these problems under the Productivity Improvements in Simulation Modeling (PRISM) project. Instead of developing new models, the PRISM approach is to develop an integrated software environment that provides a set of high-level tools for managing the entire life cycle of a simulation model: specification, code generation, documentation, verification, execution, and modification. The environment and the models will use emerging software technologies in the area of object-oriented languages, and will be hosted upon a computer workstation. Application of the PRISM strategy would allow a shift in organizational emphasis from "a model" as a product of analysis to the "process of modeling" as a more flexible and ultimately more informative means of investigating modeled systems.

PREFACE

This paper provides the conceptual background for the technical strategy being pursued by the Logistics and Human Factors Division of the Air Force Human Resources Laboratory (AFHRL/LR) in its Productivity Improvements in Simulation Modeling (PRISM) project. This project seeks to address widespread perceived deficiencies identified in many of the discrete-event simulation models used in the Air Force for logistics capability assessment. (For a detailed description of logistics capability assessment concepts and models see Nolte, 1980.)

As an Air Force Laboratory, AFHRL manages research and development (R&D) which reduces the technological risk of systems with potential future benefit to users within the Air Force. Thus, the emphasis is on programs whose benefits tend to be long term in nature, and that require the particular technical expertise the laboratory environment has to offer. Accordingly, the optimal strategy for AFHRL/LR to pursue in improving the logistics capability assessment modeling environment is to foster the development of long-term, high-risk, high-payoff technology relevant to this task. The approach outlined in this paper is consistent not only with this philosophy, but also with similar undertakings in the simulation modeling community (see, for example, Balci, 1986; Ziegler, 1987). That is, although the goal of the PRISM project is to improve the modeling process in the functional area of logistics capability assessment, the R&D parallels research in the community that is seeking to address long-recognized problems (Roth, Gass, & Lemoine, 1978; USGAO/PEMD-88-3, 1987) with simulation modeling in general.

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I. INTRODUCTION

Background

In 1987, a research and development (R&D) effort was undertaken by the Air Force Human Resources Laboratory (AFHRL) to determine the simulation modeling needs of Air Force organizations conducting logistics capability assessment. The major focus of the study was a review of discrete-event simulation models of logistics support systems, with several simulation models of air combat also investigated for relevant information on modeling practices and needs. In addition, the study gathered information on computer hardware and software technologies that could prove useful in meeting user-identified needs. AFHRL was assisted in this effort by Systems Exploration Incorporated (SEI).

A summary and analysis of this initial study may be found in Popken, Cooke, and Dickinson (1988). The findings illustrate the need for substantial improvement in the types of models and modeling support available for logistics capability assessment. In general, the models were found to be difficult to use, insufficiently documented, difficult to modify, and to require inordinate amounts of data preparation. The means to provide improvements are now more readily available as a result of recent advances in software and computer hardware technologies.

The particular strategy pursued by AFHRL's Logistics and Human Factors Division (AFHRL/LR) to improve the modeling environment, as described in this paper, is known as the Productivity Improvements in Simulation Modeling (PRISM) project. This strategy was chosen not only for being most consistent with the mission of the laboratory but, more importantly, for being the strategy which most clearly addresses the fundamental issues of user productivity, system flexibility, and structured software development.

Objectives

This paper has a twofold objective: first, to describe the basic technical features of the PRISM strategy; second, to illustrate the significance of the approach in terms of its potential to eliminate or reduce a number of basic problems associated with the use of current capability assessment simulation models.

II. MODELS AND MODEL DEVELOPMENT ENVIRONMENTS

Discrete-event simulation models have been, and continue to be, major decision support aids for logistics capability assessment. These models tend to be relatively large, are stochastic, and incorporate a fairly high level of detail. Furthermore, they tend to be general purpose in nature; that is, they persist over time for use in multiple separate studies, and explore numerous functional subareas.

The major current examples of this type of model are the Theatre Simulation of Airbase Resources (TSAR) model, and to a lesser degree, the Logistics Composite Model (LCOM). Although LCOM was originally devised to explore many different areas within logistics capability assessment, it is now used almost solely for analysis of aircraft maintenance manpower requirements. This is largely due to its acceptance and subsequent institutionalization by the Air Force manpower community. Another widely used logistics capability assessment model is the Dynamic Multi-Echelon Technique for Recoverable Item Control (Dyna-METRIC); however, it is currently analytical, rather than a simulation, and is confined to the analysis of repairable spares. There are also a number of other simulation models that have been used to a lesser degree, or whose use has been discontinued altogether.

The shortcomings of these models from the users' standpoint have been extensively documented (Popken et al., 1988). While creation of a new or enhanced general purpose simulation model could address a number of problems defined in the survey, no single model could possibly meet the needs of more than a handful of users. An Air Force Logistics Management Center (AFLMC) study (Nolte, 1980) concluded, "Capability assessment is likely to remain a diverse, fragmented, scattered effort tailored to the peculiar needs of a wide range of management applications" (p. 73). In light of this, the PRISM project does not specifically seek to modify existing models, nor to provide a particular new enhanced model. Instead, the strategy being pursued is the development of specifications for an Integrated Model Development Environment (IMDE). Such an environment would provide a set of high-level software support tools for managing the life cycle of a simulation model: specification, code generation, documentation, verification, execution, and modification. The software support tools, and the simulation models that they help create, will utilize the object-oriented paradigm.

One of the key features of the IMDE is the shift in emphasis from "a model" as a product to the "modeling process" as a more flexible, and ultimately, more informative means of learning about a system. In addition, large, general purpose models may no longer be necessary for the purpose of providing a "knowledge base" of the system. Instead, the knowledge base can be contained in the modeling environment in the form of an object-oriented intelligent data base. Simulation models would be constructed as communicating collections of these objects, which would include, for example, aircraft, aircrews, maintenance equipment, and even mission profile objects. Thus, users can benefit from an ability to reduce the sheer bulk of the models they deal with. Certainly there will always be cases where "large" models are necessary. But by drastically reducing the resource "set-up cost" of creating new models for specific projects, few motivations will remain for assuming the burden of maintaining an increasingly large model in perpetuity. Of perhaps greater significance (as described in section IV of this paper), a properly designed IMDE can reduce the need for the organizational imperative of using only those models formally approved for analysis, an additional contributing factor to the prevalence of large general purpose simulation models.

Model development environments are also quite practical from a software engineering standpoint. Developing a simulation model is similar in many respects to ordinary software development. In each case, there are requirements for initial high-level specification, documenting, coding, and testing. Unfortunately, productivity in software engineering has not kept pace with advances in hardware engineering. The cost of a unit of computational capability continues to drop yearly at a geometrical rate. On the other hand, the labor input per unit of software production has decreased only arithmetically, and on a cost basis, has likely increased (Frank, 1983). This problem is even more serious in simulation model development, where programming is only one of several costly activities. "While the cost of simulation program execution can not be ignored, the need to utilize modelers and analysts more effectively is pervasive" (Balci & Nance, 1987, p. 495). Furthermore, the structured and integrated approach of a model development environment greatly facilitates the quality assurance aspects of software engineering.

III. TECHNICAL OVERVIEW OF THE INTEGRATED MODEL DEVELOPMENT ENVIRONMENT

The notion of simulation model development environments, and their ability to address deficiencies in simulation modeling techniques, have been the subject of a number of recent research efforts (see, for example, Balmer, 1987; Hill & Roberts, 1987; Ziegler, 1987). Thus, many of the problems discussed in this paper in the context of capability assessment could also apply to simulation modeling, or even modeling in general. However, the development of a working simulation modeling environment appears to be highly context-dependent (Balci & Nance, 1987). This probably has much to do with the paucity of commercial software packages available for this purpose.

The basic structure of the IMDE proposed in this paper draws heavily upon the work of Balci (1986). In particular, we borrow the concept of organizing the software functional modules or "tools" of the overall IMDE via a layered approach (see Figure 1). Basic functions are performed by tools in the inner layer, while high-level functions are performed in the outer layer. Of particular significance, and similar to Ziegler's approach (Ziegler, 1987), the models created will specifically operate under an object-oriented conceptual framework. The target hardware for the environment is a computer workstation. Data support will be provided by an intelligent object-oriented data base integrated within the environment.

The specific layers and tools of the proposed IMDE are described below. Note, however, that the described division of functions into tools is a conceptual aid, and may not necessarily refer to specific separate software modules in an actual system. Furthermore, the set of described tools is by no means a final configuration. New tools may be added, and old tools may be modified or discontinued as the system evolves and matures.

Kernel Model Development Environment (KMDE)

The KMDE integrates the Model Development Support Environment (MDSE) and Capability Assessment Model Development Environment (CAMDE) tools into the operating system. It provides a kernel interface, communication between tools, run-time support functions, and data base access.

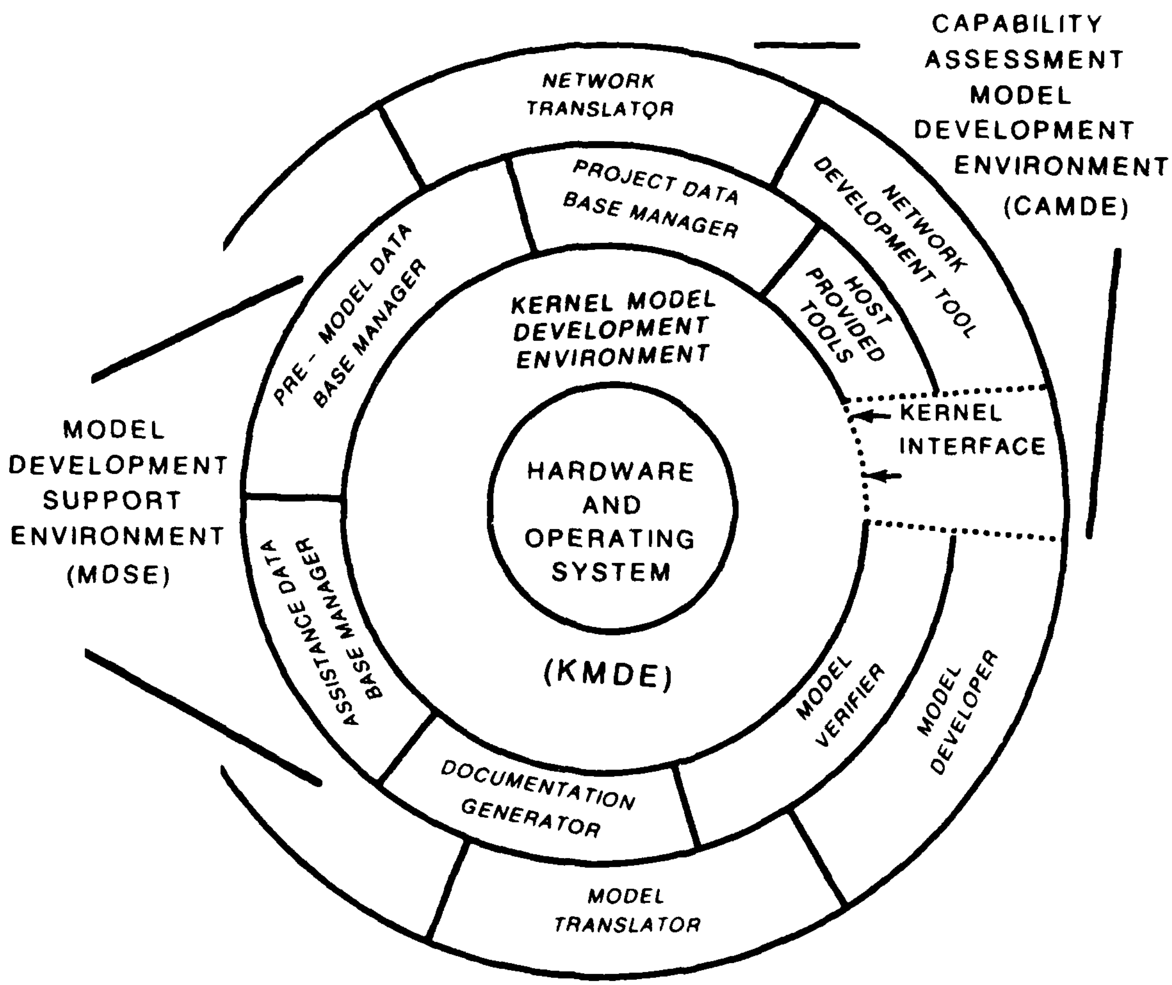

Figure 1. **Integrated Model Development Environment.**

KMDE Pre-Model Data Base

This object-oriented data base will contain prefabricated model objects and object hierarchies whose quality is assured and verified. These objects can be used as components for building models in the CAMDE. Objects may be defined as generic or specific; that is, they may be "class objects" or "instance objects."

KMDE Project Data Base

This object-oriented data base will provide temporary storage for model objects or parts that are under development or in frequent use. It will also store any documentation relating to current development projects.

KMDE Assistance Data Base

This data base will provide storage for on-line help and tutorial information about all aspects of IMDE usage.

Model Development Support Environment (MDSE)

The MDSE provides a basic set of tools for supporting the development and execution of a model. These tools may be thought of as the maximal set that may be applied generically to simulation model development for differing applications. Two categories of tools are provided: those that specifically aid the simulation model development, and host-provided tools for more general usage. All tools will communicate through the kernel interface.

MDSE Pre-Model Data Base Manager

This interactive tool will administer the Pre-Model Data Base, and allow the retrieval, browsing, and "marking" of its objects. Marked objects will reside in the data base, but will be accessible to an operating simulation model during run-time. Authorized users will have write capabilities to insert new objects or update existing objects.

MDSE Project Data Base Manager

This tool will administer the Project Data Base and allow the storage, retrieval, browsing, and "marking" of its objects. Project documents are also managed through this tool. The tool will support multiple projects.

MDSE Assistance Data Base Manager

This tool will administer the Assistance Data Base and respond to user queries about specific commands and to user invocation of tutorial assistance.

MDSE Documentation Generator

The Documentation Generator will convert internal information in the Project Data Base into printed representations, giving objects, model parts, and internal reports a "self-documenting" capability. Information regarding object processes, message ports, and hierarchies will be provided in a variety of standardized formats.

MDSE Model Verifier

The Model Verifier will be used to actually run a simulation model. Screen graphic displays may be used to monitor the progress of a simulation as directed by user-specified "debug hooks" which can segment the run into particular time spans and processes. Snapshots or traces of a model run may be saved for later examination on screen or hardcopy. In the simplest case, the Verifier will simply run a model from start to finish without interruption.

Capability Assessment Model Development Environment (CAMDE)

These tools are at the highest level of the environment, and are specific to capability assessment simulation models. They will incorporate high-level semantic and graphic aids to provide for model specification independent of specific programming language details to the maximum possible extent. These tools will communicate only through the kernel interface.

CAMDE Model Developer

This tool will provide a high-level model specification environment for hierarchical, modular, object-oriented modeling. Model specification will be independent of a particular programming language to the maximum possible extent. This environment will be specific to capability assessment modeling, to narrow the scope and requirements placed upon the tool. Screen graphics will provide visual feedback on the model linkages; for example, object hierarchies and message sender-sendee relationships.

CAMDE Model Translator

The Model Translator will convert the model specifications given by the CAMDE Model Developer into source code suitable for the interpreter/compiler, and compatible with the run-time requirements of the MDSE Model Verifier.

CAMDE Network Development Tool

This tool will provide a visual representation of model activity networks. It will allow for addition and deletion of activity arcs in a rapid interactive fashion. The tool will complement the capabilities of the Model Developer by providing an alternate means of viewing and constructing model processes, but will assume the existence of the objects involved in these processes.

CAMDE Network Translator

This tool will convert network screen inputs into executable source code suitable for the interpreter/compiler and compatible with the run-time requirements of the Model Verifier.

IV. ORGANIZATIONAL IMPLICATIONS OF THE IMDE

Some might object to the concept of an IMDE being used to generate large numbers of new and untested logistics capability assessment models. A plethora of competing models and model versions already exist. Some people would argue that establishing configuration control and standardized management procedures over some single (perhaps new) model would provide greater benefit to the actual decision makers. In the near term, before the PRISM technology matures, this could be a reasonable course of action. For the long term, however, certain aspects of the design of the IMDE suggests a compromise between a "modeling anarchy" and centralized modeling control.

Recall that the proposed design calls for two separate object-oriented data bases. The contents of the Project Data Base will be left largely to the discretion of the user. However, the Pre-Model Data Base is configured in a "read-only" mode. This data base could contain standardized logistics capability assessment objects whose characteristics are known, tested, and agreed upon by the modeling community. These models could even be placed under some form of formal configuration control. The Pre-Model Data Base Manager will then allow access to these objects during the execution of the simulation. The same concept might be extended to collections of objects or "model parts" whose interactions were previously fixed. By using this approach, analysis could progress from the use of "blessed models" to the more flexible method of building models which incorporate "blessed objects"; for example, the standardized F-15 object, or the standardized Advanced Tactical Fighter object, etc.

Credibility of the models could be maintained without discouraging independent investigative model development or rapid extension of existing models. Recent studies by the RAND corporation (Rich, Cohen, & Pyles, 1987) suggest that logistical support systems be highly flexible and adaptable to deal with the uncertainties of a wartime dynamic. This being the case, models that are fixed and difficult to modify would be inappropriate. "The expectation of a rapidly changing 'messy' modeling context leads to an emphasis on rapid interactive model development and investigation, and modular model structures permitting ready extension and modification" (Balmer, 1987, p. 481).

V. CURRENT STATUS AND FUTURE PLANS

An Integrated Model Development Environment can provide a powerful set of tools for developing discrete-event capability assessment simulation models. The synergistic effects of the object-oriented paradigm and integrated software development tools are of particular significance. As an illustration, the results of independent research (Stairmand & Kreutzer, 1988) suggest that "... object-oriented simulation environments hosted on powerful personal workstations may well offer major breakthroughs in terms of effectiveness and user acceptance" (p. 143). Furthermore, maximum flexibility can be designed into models developed by such a system to cope with rapid changes in the modeling context. Increased productivity, reduced training time, and faster project completion are the environment's natural byproducts.

In view of these potential benefits, AFHRL is pursuing a multi-pronged approach to the task of technology development in the PRISM project. Initially, separate research activities will be studying the areas of:

1. an object-oriented data base with an efficient interface to an object-oriented simulation,

2. the use of interactive graphical programming techniques for developing object-oriented simulation models.

These two activities are similar in that they focus on high-risk elements of the IMDE. They are being initiated in fiscal year 1988 (FY88) and are planned to be approximately 2 years in length. IMDE system requirements analysis and system design will begin in FY89 and require approximately 18 months. The design effort will provide for soliciting feedback from potential users of the IMDE, and incorporating this feedback into the development process. In 1990, the second phase of the project will integrate the results of the two research activities above, the system design, and the user feedback, into the development of a prototype IMDE of the form described in Section III. This second phase will require approximately 18 additional months.

One of the first tasks of the IMDE will be a demonstration of its capabilities through construction of relatively large-scale modules of logistics support systems. Performance tests and comparisons to existing models would be part of this demonstration phase. If the system achieves a high level of quality and acceptance, a follow-on research effort may be initiated to determine ways of providing on-line access to standard Air Force data base systems. In this way the system could become fully integrated, achieving maximal productivity and data integrity.

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